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OUTLINES OF WORK
AND
EXPERIMENTS
IN THE
FOUR SCIENCES

PHYSIOLOGY,
BOTANY,
ZOOLOGY,
CHEMISTRY.

By M. L. SEYMOUR,
Professor of Natural Sciences, Illinois State Normal University.

1886.

Published by Seymour & Cook, Normal, Ill.

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Pantagraph Stationery Company, Printers.
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PREFACE.

The Outlines, Principles, and Experiments here presented have been in constant use for eight years in the Illinois State Normal University.

They have been many times revised and corrected, and are now only general and illustrative in character.

While they are applicable to any text-book on the sciences treated, it is not claimed for them that they are infallible or exhaustive.

It is hoped they may be helpful to teachers and students desiring *to know* by orderly study or by experimental proof.

M. L. S.

Sarah [illegible]

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PHYSIOLOGY.

SKELETON.

(201)

- 1. Head.
  (22)
  - 1. Cranium.
    (8)
    - Frontal 1
    - Parietal 2
    - Temporal 2
    - Occipital 1
    - Sphenoid 1
    - Ethmoid 1—8
  - 2. Face.
    (14)
    - Upper Maxillary 2
    - Lower Maxillary 1
    - Malar 2
    - Palatine 2
    - Lachrymal 2
    - Turbinated 2
    - Nasal 2
    - Vomer 1—14.
- 2. Trunk.
  (55)
  - 1. Sternum.
    (3)
    - Handle.
    - Blade.
    - Point—3.
  - 2. Spinal column.
    (24)
    - Cervical 7
    - Dorsal 12
    - Lumbar 5—24
  - 3. Ribs.
    (24)
    - True 14
    - False 6
    - Floating 4—24
  - 4. Pelvis.
    (4)
    - Innominata 2
    - Sacrum 1
    - Coccyx 1—4

SKELETON—Continued.

3. Extremities.
   1. Upper.
      - (64) 1. Shoulder.
        - (4) Scapula 2
        - Clavicle 2—4
      - 2. Arm.
        - (2) Humerus 2
      - 3. Forearm.
        - (4) Radius 2
        - Ulna 2—4
      - 4. Hand.
        - (54) 1. Carpus.
          - (16)

Scaphoid	2	Trapezium	2
Semilunar	2	Trapezoid	2
Cuneiform	2	Capitate	2
Pisiform	2	Unciform	2

- 2. Metacarpus—10.
- 3. Phalanges—28.

2. Lower.
   - (60) 1. Thigh.
     - (2) Femur 2
   - 2. Leg.
     - (6) Tibia 2
     - Fibula 2
     - Patella 2
   - 3. Foot.
     - (52) 1. Tarsus.
       - (14) Oscalcis 2
       - Astragalus 2
       - Cuneiform
         - External 2
         - Middle 2
         - Internal 2
       - Scaphoid 2
       - Cuboid 2
     - 2. Metatarsus 10
     - 3. Phalanges 28

SPINAL COLUMN.

FOUR CONES.

I.

The first cone consists of the lower six cervical vertebræ, the atlas forming the capital of the column. These vertebræ form the frustum of an upright cone.

II.

The second cone consists of the upper four dorsal vertebræ. These form the frustum of an inverted cone.

III.

The third cone consists of the lower eight dorsal, and the five lumbar vertebræ, forming the frustum of an upright cone.

IV.

The sacrum and coccyx form an inverted cone.

The bases of these cones meet at places where the greatest strength is required, and near where the limbs are joined to the spinal column.

Between these bases are the places of greatest flexibility.

EXPERIMENTS SUGGESTED.

BONES.

1. Place a rib, fresh or old, in a well-corked lamp chimney that is filled with one part hydrochloric acid and six parts water, by volume.
2. Burn a bone, and carefully remove from grate. Examine.
3. Get a leg of sheep. Examine for periosteum on the bone and at the joint.
4. Saw a long bone through condyle and shaft. Compare.
5. Dissect a joint. Distinguish tendons from ligaments.

STRUCTURAL DIFFERENCES

BETWEEN THE SKELETONS OF THE MALE AND THE FEMALE

In the skeleton of the female the following points appear in contrast:

1. The head is smaller.
2. The trunk is longer.
3. The phalanges slimmer.
4. The clavicle less curved and longer.
5. The pelvis:
    - (*a*) Transverse diameter greater.
    - (*b*) Ilium thinner.
    - (*c*) Sacrum broader and shorter.
6. The femur has a longer neck, and is more nearly rectangular.
7. The ribs are more curved.

POINTS ON THE HAND.

I.

If the center of the palm be placed on a sphere and the digits equally spread, their tips lie in the same plane.

II.

If a straight-edge be placed transversely across the palm, the fingers may press upon it with nearly equal force.

III.

The thumb can be made to oppose each finger.

IV.

The index finger can be used as a pointer.

These points are peculiar to the human hand. They should be fully illustrated.

MUSCLES.

- I. Definition.
- II. Composition.
    - 1. Nitrogen.
    - 2. Oxygen.
    - 3. Hydrogen.
    - 4. Carbon.
    - 5. Salts.
- III. Covering.
- IV. Form.
    - 1. Fusiform.
    - 2. Penniform.
    - 3. Radiate.
- V. Structure.
    - 1. Bundles of fibers.
    - 2. Fibrillae.
    - 3. Sarcous elements.
    - 4. Covering of each.
- VI. Kinds as to
    - 1. Will.
        - 1. Voluntary.
        - 2. Involuntary.
    - 2. Position.
        - 1. Superficial.
        - 2. Deep-seated.
    - 3. Structure.
        - 1. Striated.
        - 2. Non-striated.
    - 4. Arrangement.
        - 1. Single.
        - 2. Pairs.
- VII. Attachment.
    - 1. Origin.
    - 2. Insertion.

MUSCLES—Continued.

VIII. Contraction.
  1. Beginning.
  2. Extent.
  3. Rapidity.

IX. Uses.
  1. Move levers.
  2. Move tissues.
  3. Protection.
  4. Beauty.

X. Classes.
  1. Flexors.
  2. Extensors.
  3. Abductors.
  4. Adductors.
  5. Pronators.
  6. Supinators

XI. Hygiene.
  1. Exercise moderately.
  2. Rest gradually.
  3. Cover after use.

SUGGESTIONS.

1. Show structure of striated muscle by diagram, and with thread. Wrap single thread, four inches long, with tissue paper. Such thread represents a fiber, its covering, the sarcolemma. Unwind thread to show fibrillae. In this way, build up the representation of a fasciculus and a muscle.

2. Bandage the arm, over biceps muscle, with writing paper. Quickly flex forearm.

3. Hold a book at arms length two minutes. Explain.

4. Place a large flat weight on table. Grasp weight with right hand, palm up, and turn weight to the right. Now to the left.

Why are gimlets made to turn to the right?

BLOOD.

- I. Definition.
    - (Is it alive?)
- II. Specific gravity.
- III. Temperature.
- IV. Alkaline or acid?
- V. Color.
    - 1. In what part?
    - 2. Cause.
- VI. Kinds.
    - 1. Arterial.
    - 2. Venous.
        - 1. Distinguished
            - 1. By color.
            - 2. Nutritive value.
- VII. Composition.
    - 1. Plasma.
        - 1. Fibrine.
            - 1. Coagulation.
                - 1. Cause.
                - 2. Purpose.
        - 2. Serum.
    - 2. Corpuscles.
        - 1. Red.
            - Peculiarity in mammals.
            - 1. Why red.
            - 2. Shape.
            - 3. Size.
            - 4. Office.
        - 2. White.
- VIII. Amount.
- IX. Functions.
- X. Transfusion.

HEMORRHAGE.

I. Definition.

1. Etymological.
2. Applied.

II. Causes.

1. Disease.
2. Accident.

III. Treatment.

1. Nature's method.
   1. Coagulation.
   2. Contraction of muscular fibres.
      1. Transverse.
      2. Longitudinal.
   3. Syncope.
2. Artificial methods.
   1. Pressure.
   2. Cold.
   3. Position.
   4. Torsion.
   5. Ligation.
   6. Cautery.
   7. Styptics.
   8. Acupressure.

DETERMINATION OF THE BLOOD.

The blood may be made to flow to or from any part of the body by exercise, physical or mental, by heat or cold, by food, drink, or emotion.

These points are capable of fullest illustration in class, and should teach many important facts in Hygiene.

Draw from the class ways known to them for stopping hemorrhage.

Have the philosophy of such methods explained.

Picture emergencies and call for treatment.

When studying, why are the feet cold?

FINDING ARTERIES.

1. Place forefinger on radial artery at wrist; on facial artery at notch in lower jaw, on under side.

Press on the temple and below the ear. What arteries?

Place the hollow at the knee on the patella of the other leg. Watch the foot.

Place some object two inches in diameter in the axilla of the arm. Bring the elbow as near the side as possible. With the other hand feel for the pulse at the wrist.

These, and other experiments, may teach what to do in case of hemorrhage of these arteries or their branches.

CIRCULATION.

- I. Definition.
    - 1. Etymological.
    - 2. Applied.
- II. Objects.
    - 1. Food for Growth and Repair.
    - 2. Remove waste.
    - 3. Heat.
- III. Organs.
    - 1. Heart.
        - 1. Definition.
        - 2. Position.
        - 3. Size.
        - 4. Covering.
        - 5. Auricles.
        - 6. Ventricles.
        - 7. Valves.
            - 1. Bicuspid.
            - 2. Tricuspid.
            - 3. Semilunar.
        - 8. Sounds.
        - 9. Movements.
            - 1. Diastole.
            - 2. Systole.
    - 2. Arteries.
        - 1. Definition.
        - 2. Position.
        - 3. Structure.
        - 4. Branches.
    - 3. Veins.
        - (Same points.)
    - 4. Capillaries.
- IV. Kinds.
    - 1. Pulmonic.
    - 2. Systemic.
- V. Causes.
    - 1. Heart force.
    - 2. Contraction of muscular fibres in arteries and veins.
    - 3. Capillary attraction.
    - 4. Disturbance of equilibrium of forces.
- VI. Hygiene.
    - 1. Free circulation.
    - 2. Impeded.
        - 1. Dress.
        - 2. Colds.

RESPIRATION.

- I. Definition.
    - 1. Etymological.
    - 2. Applied.
- II. Objects.
- III. Condition.
- IV. Law.
- V. Acts.
    - 1. Inspiration.
    - 2. Expiration.
- VI. Organs.
    - 1. Larynx.
        - 1. Definition.
        - 2. Position.
        - 3. Structure.
        - 4. Use.
        - 5. Parts.
            - 1. Epiglottis.
            - 2. Thyroid.
            - 3. Cricoid.
            - 4. Arytenoids.
            - 5. Vocal ligaments.
    - 2. Trachea.
        - 1. Definition.
        - 2. Position.
        - 3. Length.
        - 4. Structure.
        - 5. Divisions.
        - 6. Uses.
    - 3. Lungs.
        - 1. Position.
        - 2. Lobes.
        - 3. Covering.
        - 4. Structure.
        - 5. Color.
        - 6. Movements.
        - 7. Capacity.
    - 4. Diaphragm.

RESPIRATION—Continued.

VII. Diseases.
  1. Diphtheria.
  2. Bronchitis.
  3. Pneumonia.
  4. Consumption.
  5. Pleurisy.
  6. Asthma.
  7. Croup.
  8. Asphyxia.
    1. Strangulation.
    2. Suffocation.
    3. Compression.
    4. Drowning.

VIII. Hygiene.
  1. Air.
  2. Food.
  3. Dress.
  4. Exercise.

SUGGESTIONS.

1. Measure around chest after a forced expiration and inspiration.

2. Count respirations by placing tips of fingers in front of clavicle.

3. Give five reasons for breathing through the nose.

4. Movements and function of diaphragm.

5. Distinguish between strangulation, suffocation, compression, drowning.

Treatment.

VENTILATION.

- I. Definition.
    - 1. Etymological.
    - 2. Applied.
- II. Why necessary.
    - 1. Consumption of oxygen.
        - 1. Respiration.
        - 2. Combustion.
    - 2. Removal of waste products.
- III. Implies what?
- IV. How secured in summer? In winter?
- V. Ways of heating.
    - 1. Open grate.
    - 2. Enclosed fire.
    - 3. Hot air.
    - 4. Steam.
    - 5. Hot water.
- VI. Admission of air.
    - 1. Where?
    - 2. Cautions.
- VII. Exit of air.
    - 1. Where?
    - 2. Cautions.
- VIII. Respiratory products.
    - 1. What are they?
    - 2. Their character.
    - 3. Where in cold rooms? In warm rooms?
    - 4. Their danger.
- IX. Combustion products.
- X. Ventilation of sleeping rooms.

SUGGESTIONS.

1. Hold cold plate over burning lamp.

2. In like manner, hold an inverted pint jar. Test for CO_2 with lime water.

3. Open upper and lower sash two inches. Test currents with torch of cotton wet with alcohol.

4. Breathe in empty pint jar. Test for CO_2.

5. In an occupied room warmed by a stove, show three causes for bad air, and three ways that oxygen is used up.

6. Give three reasons for ventilation of sleeping rooms. Give three directions for doing it.

DIGESTION.

- I. Definition.
  - 1. Etymological.
  - 2. Applied.

- II. Acts.
  - 1. Prehension.
  - 2. Mastication.
  - 3. Insalivation.
  - 4. Deglutition.

- III. Processes.
  - 1. Liquefaction.
  - 2. Chemical Changes.
  - 3. Absorption.
  - 4. Assimilation.

- IV. Organs.
  - 1. Glands.
    - 1. Parotid.
    - 2. Submaxillary.
    - 3. Sublingual.
  - 2. Alimentary Canal.
    - 1. Definition.
    - 2. Covering.
    - 3. Lining.
    - 4. Parts.
      - 1. Mouth.
        - 1. Definition.
        - 2. Openings.
        - 3. Bound.
      - 2. Pharynx.
        - 1. Definition.
        - 2. Openings—7.
      - 3. Esophagus.
        - 1. Definition.
        - 2. Position.
        - 3. Structure.
        - 4. Action.
      - 4. Stomach.
        - 1. Definition.
        - 2. Position.
        - 3. Orifices.
        - 4. Capacity.
        - 5. Structure.
        - 6. Action.
          - 1. Mechanical.
          - 2. Chemical.
          - 3. Solvent.
      - 5. Intestines.
        - 1. Small.
          - 1. Duodenum.
          - 2. Jejunum.
          - 3. Ileum.
          - 4. Mesentery.
          - 5. Thoracic Duct.
        - 2. Large.
          - 1. Ascending Colon.
          - 2. Coecum.
          - 3. Transverse Colon.
          - 4. Descending Colon.

- V. Aids.
  - 1. Liver.
    - 1. Definition.
    - 2. Position.
    - 3. Size.
    - 4. Lobes.
    - 5. Structure.
    - 6. Pipes.
    - 7. Bile.
      - 1. Properties.
      - 2. Uses.
  - 2. Pancreas.
    - 1. Definition.
    - 2. Position.
    - 3. Structure.
    - 4. Duct and Liquid.
    - 5. Uses.

- VI. Hygiene.
  - 1. Food.
    - 1. Quality and Quantity.
    - 2. Preparation.
    - 3. Intervals.
  - 2. Drinks.
    - 1. Beverages.
    - 2. Alcoholic effects.
  - 3. Habits.
    - 1. Time of eating.
    - 2. Way of eating.
    - 3. Sociability.

SKIN.

I. Definition.
II. Structure.
III. Color.
IV. Glands.
   1. Sebaceous.
   2. Sudoriparous.

V. Functions.
   1. Protection.
   2. Absorption.
   3. Perspiration.
   4. Sensation.

VI. Modifications.
   1. Hair.
      1. Composition.
      2. Structure.
      3. Color.
      4. Care.
   2. Nails.
      1. Structure.
      2. Mode of growth.
      3. Uses.
   3. Mucous membrane.
      1. Definition.
      2. Structure.
      3. Illustrations.
   4. Serous membrane.
      (Same points.)
   5. Connective tissue.
      1. Definition.
      2. Illustration.
   6. Teeth.
      1. Definition.
      2. Parts.
      3. Structure.
      4. Temporary, $i\frac{2-2}{2-2}$, $c\frac{1-1}{1-1}$, $m\frac{2-2}{2-2}$.
      5. Permanent, $i\frac{2-2}{2-2}$, $c\frac{1-1}{1-1}$, $p.m\frac{2-2}{2-2}$, $m\frac{3-3}{3-3}$.
      6. Care.

VII. Care.
   1. Bathing.
      1. Time.
      2. Manner.
   2. Clothing.
   3. Temperature.

NERVOUS SYSTEM.

I. Definition.

II. Function.

III. Composition.
1. Gray matter.
2. White matter.
3. Structure and office of each.

IV. Divisions.
1. Sympathetic.
   1. Location.
   2. Function.
   3. Covering.
2. Cerebro-spinal.
   1. Brain.
      1. Definition.
      2. Location.
      3. Coverings.
         1. Pia mater.
         2. Arachnoid.
         3. Dura mater.
      4. Parts.
         1. Cerebrum.
            1. Definition.
            2. Location.
            3. Function.
            4. Hemispheres.
            5. Appearance.
         2. Cerebellum (same points).
         3. Medulla oblongata.
            1. Definition.
            2. Location.
            3. Form.
            4. Function.
   2. Spinal cord.
      1. Definition.
      2. Position.
      3. Covering.
      4. Nerves.
         1. Sensory.
         2. Motory.
      5. Reflex action.
         1. Definition.
         2. Illustration.

V. Hygiene.
1. Duration of use.
2. Sleep.
3. Rest.
4. Diversion.

EYE.

- I. Definition.
- II. Position.
- III. Protection.
  - 1. Eyebrow.
    - 1. Position.
    - 2. Uses.
      - 1. About light.
      - 2. Foreign bodies.
  - 2. Eyelids.
    - 1. Shape.
    - 2. Structure.
      - 1. Cartilage.
      - 2. Eyelashes.
      - 3. Glands.
    - 3. Uses.
      - 1. Protection.
      - 2. Lubrication.
  - 3. Glands.
    - 1. Lachrymal.
      - 1. Position.
      - 2. Structure.
    - 2. Palpebral.
- IV. Size.
  - 1. Diameters.
    - 1. Lateral.
    - 2. Longitudinal.
- V Coats.
  - 1. Conjunctiva.
  - 2. Sclerotica.
    - Complement—cornea.
      - 1. Shape.
      - 2. Structure.
      - 3. Function.
  - 3. Choroid.
    - Complement—iris.
      - 1. Shape.
      - 2. Structure.
      - 3. Pupil.
      - 4. Action.
  - 4. Retina.
    - 1. Definition.
    - 2. Structure.
    - 3. Function.

EYE—Continued.

- VI. Lenses.
  - 1. Aqueous humor.
    - 1. Where?
    - 2. Amount.
    - 3. Use.
  - 2. Crystalline.
    - 1. Position.
    - 2. Shape and covering.
    - 3. Structure.
    - 4. Function.
  - 3. Vitreous.
    - 1. Mass.
    - 2. Covering.
    - 3. Function.
  - 4. Optic nerve.
- VII. Hygiene.
  - 1. Extra Use.
  - 2. Strong and weak light.
  - 3. Bathing.
  - 4. Friction.
  - 5. Foreign bodies.

COMPOSITION OF HAIR.

1. Take a large test-tube half filled with human hair. In the mouth of the tube insert a cork, through which projects a small tube.

2. Heat the test-tube and hold a cold plate over the issuing steam.

3. At a higher heat hold a silver coin over the issuing gas.

4. Change the coin for red litmus paper.

5. Examine the charred mass.

QUERIES.

1. The Turkish bath may be followed by a cold douche without injury.

2. A draft of cool air upon a small portion of the body, heated from exercise, is likely to be injurious.

3. Take the temperature of the body before and after running. Note a difference of one or two degrees. Soon the temperature falls to normal.

4. Contrast the effects of dry and moist air upon the skin and feelings.

5. Account for the lack of spirit in a school on dark, cloudy days.

BOTANY.

- I. Definition.
    - 1. Etymological.
    - 2. Applied.
- II. Kinds.
    - 1. Structural.
    - 2. Physiological.
    - 3. Systematic.
        - 1. Artificial.
        - 2. Natural.
- III. Obiect of study.
    - 1. Plant.
        - 1. Definition.
        - 2. Kinds.
            - 1. Phenogamous.
            - 2. Cryptogamous.
        - 3. Functions.
            - 1. Endow inorganic matter with life.
            - 2. Reproduction.
            - 3. Plant food.
            - 4. Purify the air.
        - 4. Uses.
            - 1. Food.
            - 2. Shelter.
            - 3. Clothing.
            - 4. Fuel.
            - 5. Beverages.
            - 6. Mechanics.
            - 7. Medicine.
            - 8. Dyes.
            - 9. Perfumes.
            - 10. Paper.
            - 11. Ink.
            - 12. Ornament.

REPRODUCTION.

- I. Definition.
    - 1. Etymological.
    - 2. Applied.
- II. Organs.
    - 1. Stamens.
    - 2. Pistils.
    - 3. Spores.
- III. Seed.
    - 1. Definition.
    - 2. Covering.
    - 3. Funiculus.
    - 4. Hilum.
    - 5. Micropyle.
    - 6. Albumen.
    - 7. Chalaza.
    - 8. Embryo.
        - 1. Definition.
        - 2. Cotyledons.
            - 1. Monocotyledons.
            - 2. Dicotyledons.
            - 3. Polycotyledons.
        - 3. Radicle.
        - 4. Plumule.
    - 9. Germination.
        - 1. Definition.
        - 2. Conditions.
            - 1. Germ.
            - 2. Food.
            - 3. Moisture.
            - 4. Heat.
            - 5. Oxygen.

ROOT.

- I. Definition.
- II. Kinds.
  - 1. Primary.
    - 1. Conical.
    - 2. Napiform.
    - 3. Fusiform.
    - 4. Ramose.
    - 5. Corallorhiza.
  - 2. Secondary.
    - 1. Definition.
    - 2. Illustrate.
  - 3. Aerial.

For the understanding of the short outline above, a great variety of roots should be brought in class.

Much care should be exercised as to the definitions, and all illustrations should be shown by drawings.

What roots come from slips and cuttings?

What are the small root-like bodies on a beet?

Classify the roots of carrot, radish, cabbage, corn, sweet potato, *onion.*

STEM.

- I. Aerial.
    - 1. Herbaceous.
        All about
        - 1. Annuals.
        - 2. Biennials.
        - 3. Perennials.
    - 2. Fruticose.
        - 1. Erect.
        - 2. Climbers.
        - 3. Trailers.
    - 3. Arboreous.
        - 1. Excurrent.
        - 2. Deliquescent.
- II. Subterranean.
    - 1. Rhizoma.
    - 2. Tuber.
    - 3. Corm.
    - 4. Bulb.
- III. Forms of stems.
    - 1. Culm.
    - 2. Caudex.
    - 3. Branches.
        - 1. Sucker.
        - 2. Stolon.
        - 3. Offsets.
        - 4. Runners.

PROPAGATION OF PLANTS.

I. Definition.

II. Modes.
- 1. Subterranean stems.
    - 1. Rhizoma.
    - 2. Tuber.
    - 3. Corm.
    - 4. Bulb.
    - 5. Sucker.
    - 6. Adventitious buds.
- 2. Aerial stems.
    - 1. Phytomer.
    - 2. Slips.
    - 3. Cuttings.
    - 4. Bulblets.
    - 5. Layering.
        - 1. Stolon.
        - 2. Runner.
        - 3. Offsets.

What cautions are necessary in cutting slips?

How are sweet potatoes multiplied?

In which way can fruit be produced soonest, from the seed, or in any one of the above ways? Why?

What bearing has this on early wild flowers?

GRAFTING.

Grafting is properly setting a bud or scion into a stock or root.

PRINCIPLES.

I.

Each species of plants will produce its like.

II.

Successful grafting is confined to plants of the same genus.

III.

The scion or bud, must be set in the line of the circulation of the sap.

The following ways are common: cleft, splice, saddle, tongue.

Root-grafting leaves no scar in sight, hence this way prevails with nurserymen.

The ways of grafting should be shown the class, and each member required to make drawings of these methods.

LEAF.

- I. Definition.
- II. Venation.
  - 1. Parallel-veined.
  - 2. Netted-veined.
- III. Arrangement.
  - 1. Radical.
  - 2. Opposite.
  - 3. Alternate.
    - (All about ranking).
- IV. Parts.
  - 1. Blade.
    - 1. Parenchyma.
    - 2. Epidermis.
    - 3. Midrib.
    - 4. Veins.
    - 5. Veinlets.
  - 2. Petiole.
  - 3. Stipules.
- V. Vernation.
  - 1. Independent.
    - 1. Straight.
    - 2. Conduplicate.
    - 3. Circinate.
    - 4. Plaited.
    - 5. Convolute.
    - 6. Involute.
    - 7. Revolute.
  - 2. Relative.
    - 1. Valvate.
    - 2. Contorted.
    - 3. Imbricate.
    - 4. Plicate.

TERMS FOR OUTLINE.

1. Linear.
2. Lanceolate.
3. Oblong.
4. Elliptical.
5. Oval.
6. Ovate.
7. Orbicular.
8. Oblanceolate.
9. Spatulate.
10. Obovate.
11. Cuneate.

TERMS FOR BASE.

1. Cordate.
2. Reniform.
3. Auriculate.
4. Sagittate.
5. Hastate.
6. Peltate

TERMS FOR APEX.

1. Acuminate.
2. Acute.
3. Cuspidate.
4. Mucronate.
5. Aristate.
6. Obtuse.
7. Truncate.
8. Retuse.
9. Emarginate.
10. Obcordate.

TERMS FOR MARGIN.

1. Entire.
2. Serrate.
3. Dentate.
4. Crenate.
5. Repand.
6. Sinuate.
7. Incised.
8. Lobed.
9. Cleft.
10. Parted.
11. Divided.

Compound leaves are Pinnate or Palmate. Leaves are also Perfoliate and Equitant.

Pupils will get the best understanding of all these terms if required to cut leaves of paper to correspond.

Drawings in every case should be required.

If this work is thoroughly done most trees can be classified, and the scientific names given from a careful examination and description of their leaves.

To tell a tree at sight is not less important than to name a flower.

POINTS DISTINGUISHING EXOGENS FROM ENDOGENS.

EXOGENS HAVE:

1. Dicotyledonous or polycotyledonous seeds.
2. Distinct wood, bark, and pith.
3. Bundles of woody fibers arranged regularly throughout the stem.
4. Usually netted-veined leaves.
5. Flowers generally in 4's or 5's, rarely in 3's.
6. Unlimited growth.

ENDOGENS HAVE:

1. Monocotyledonous seeds.
3. No distinct wood, bark or pith.
3. Bundles of woody fibers scattered irregularly throughout the stem.
4. Usually parallel-veined leaves, sheathing at base.
5. Flowers generally in 3's rarely in 5's and terminal.
6. Limited growth.

OUTLINES.

The following outlines for describing leaf, stem, and flower, suggest the order of description.

If all members of the class memorize them, the exercise will be a *thinking* one.

To illustrate: The leaf of Rosa lucida, or shining rose, is netted-veined, alternate, leaflets opposite, odd one petiolate, others sessile, stipulate, elliptical, obtuse at each end, serrate, upper surface shiny, lower dull and veiny.

In this manner many leaves may be described in a few minutes, and all be able to detect omissions, or mistakes.

OUTLINE FOR DESCRIBING LEAF.

1. Venation.
2. Arrangement.
3. Simple or compound.
4. Petiole.
5. Stipules.
6. Outline.
7. Base.
8. Apex.
9. Margin.
10. Surface.

OUTLINE FOR STEM.

1. Amount of fibers.
2. Arrangement of fibers.
3. Form.
4. Direction.
5. Branches.
6. Joints.
7. Surface.
8. Height.

OUTLINE FOR FLOWER.

1. Inflorescence.
2. Special kind.
3. Plan.
4. Calyx.
5. Corrolla.
6. Stamens.
7. Pistil.

FOUR PRINCIPLES.

I.—NAMES.

The names of the orders in botany are Latin adjectives, agreeing number, gender, and case with the noun *plantae* understood. They correspond to the word *family* in English. and most of them end in *aceae.*

II.—DERIVATION.

The names of the orders are derived from some genus of the order, or from some marked characteristic of the plants of the order.

III.—CAPITALIZATION.

The names of the orders, classes, and genera should begin with capitals. The names of the species should begin with small letters, unless derived from proper names or used as nouns.

IV.—PRONUNCIATION.

In the pronunciation of the names of the orders, genera, and species, the vowel marked receives the accent. The grave accent (\`) shows such vowel to be long; the acute (′), short.

FOUR PRINCIPLES ILLUSTRATED.

I.

The name of the first order in botany, if read in full, would be Plantae Ranunculaceae.

All the names of orders, excepting about thirteen, end in aceae. See index of text-book for exceptions.

Linnaeus named these so truthfully no botanist has ventured to change them.

II.

Aceae is an adjective ending. In most names of orders, the name of some genus, typical of all the plants of the order, is taken, and the name of the order formed. See *Rosa.*

III.

See Gray's School and Field Book, p. 43.

IV.

From an examination of the names of plants in any order, it will be seen that only two marks are used in botany to show pronunciation, and that each mark serves two purposes at the same time—accent and length of vowel.

FLOWER.

I. Definition.

II. Office.

III. Inflorescence.

1. Determinate.
   1. Cyme.
   2. Fascicle.
   3. Glomerule.
2. Indeterminate.
   1. Raceme.
   2. Corymb.
   3. Umbel.
   4. Spike.
   5. Head.
   6. Catkin.
   7. Panicle.
   8. Thyrsus

IV. Organs.

1. Floral envelopes.
   1. Calyx.
   2. Corolla.
2. Essential organs.
   1. Stamens.
      1. Filament.
      2. Anther.
   2. Pistil.
      1. Ovary.
      2. Style.
      3. Stigma.

V. Plan.

1. Perfect.
2. Imperfect.
3. Complete.
4. Incomplete.
5. Regular.
6. Irregular.
7. Symmetrical.
8. Unsymmetrical.

STAMEN.

- I. Definition.
- II. Filament.
  - 1. Definition
  - 2. Office.
- III. Anther.
  - 1. Definition.
  - 2. Office.
  - 3. Position.
    - 1. Extrorse.
    - 2. Introrse.
  - 4. Shape.
    - 1. Oblong.
    - 2. Kidney-shaped.
    - 3. Arrow-shaped.
  - 5. Cells.
    - 1. Number.
    - 2. Position.
  - 6. Attachment.
    - 1. Innate.
    - 2. Adnate.
    - 3. Versatile.
  - 7. Dehiscence.
    - 1. Porous.
    - 2. Valvular.
    - 3. Transverse.
    - 4. Longitudinal.

PISTIL.

I. Definition.

II. Kinds.
    1. Simple.
    2. Compound.

III. Office.

IV. Parts.
    1. Ovary.
        1. Definition.
        2. Parts.
            1. Placenta.
            2. Dissepiments.
            3. Cells.
            4. Ovules.
                1. Definition.
                2. Parts.
                    1. Funiculus.
                    2. Hilum.
                    3. Chalaza.
                3. Kinds.
                    1. Orthotropous.
                    2. Anatropous.
                    3. Amphitropous.
                    4. Campylotropous.
                4. Direction.
                    1. Erect.
                    2. Ascending.
                    3. Horizontal.
                    4. Pendulous.
                    5. Suspended.
    2. Style.
    3. Stigma.
        1. Definition.
        2. Shape.
            1. Cleft.
            2. Scrolled.
            3. Globose.
            4. Capitate.
            5. Oblong.

FRUIT.

I. Definition.
  1. Seed or spore.
  2. Botanical.

II. Parts.
  1. Seed—its covering.
  2. Pericarp.
     1. Epicarp.
     2. Mesocarp.
     3. Endocarp.

III. Dehiscence.
  1. Septicidal.
  2. Loculicidal.
  3. Septifragal.
  4. Circumscissile.

IV. Kinds.
  1. Simple.
     1. Fleshy.
        1. Pepo.
        2. Pome.
        3. Berry.
     2. Stone—Drupe.
     3. Dry.
        1. Dehiscent.
           1. Follicle.
           2. Legume.
           3. Silique.
           4. Capsule.
        2. Indehiscent.
           1. Achenium.
           2. Nut.
           3. Caryopsis.
           4. Samara.
  2. Aggregate.
  3. Accessory.
  4. Multiple.

NUTRITION OF PLANTS.

- I. Organs.
    - 1. Kinds.
        - 1. Root.
        - 2. Stem.
        - 3. Leaf.
    - 2. Morphology.
    - 3. Structure.
        - 1. Cells.
            - 1. Cellulose.
            - 2. Protoplasm.
            - 3. Nucleus.
        - 2. Ducts.
            - 1. Dotted.
            - 2. Spiral.
            - 3. Scalariform.
        - 3. Fibers.
    - 4. Functions.
        - 1. Absorption.
        - 2. Assimilation.
        - 3. Growth.
- II. Food.
    - 1. Kinds.
        - 1. Water.
        - 2. Gases.
        - 3. Earthy matter.
    - 2. Distribution.
        - Sap.
            - 1. Kinds.
            - 2. Movements.

SHOW WHY THE FOLLOWING ARE MISNOMERS:

Peanut.
Nutmeg.
Blackberry.
May-apple.
Egg-plant.
Ground-cherry.
Strawberry.
Raspberry.
Pine-apple.
Custard-apple.
Tuberose.
Butternut.

In the analysis of plants, it will be found best to have no books used until all parts of the plant have been carefully examined.

Then all take books, and each be responsible for immediate reading.

In doing this, the student's opinion of the plant is held first, and the book is compared with it.

Besides, this opinion is open to criticism of all as the student reads. for no one likes to surrender his view of what he has seen and formed judgment upon.

If the examination of the plant and the use of the book are kept distinct, there comes a joy when one's exact statements are read in print.

If, however, one must look again at the plant, there is a feeling of humiliation at not being able to see as closely and judge as truthfully as the describer.

ZOOLOGY.

But little information will be found in the outlines and hints given under this subject.

Zoology simple and pure, does not consist in classification.

The pupil must study animals, dissect, compare, and read.

The dissection of typical animals is genuine work in zoology.

Not less valuable is the close observation of animals in order to group them because of likenesses, or to separate them because of differences.

A few outlines and some statements of chief characters of certain groups are given because they may prove suggestive and serve as guides.

THE WORK BEGUN.—EXAMINATION OF CRAY-FISH.

CRAY-FISH.

I. Name.

II. Exoskeleton.

III. Regions.
    1. Cephalo-thorax.
        1. Cervical groove.
        2. Cephalon.
            Somites 6.
        3. Thorax.
            1. Somites 8.
            2. Carapace.
                1. Rostrum.
                2. Tergum.
                3. Branchiostegites.
    2. Abdomen.
        1. Somites 6.
        2. Telson.

IV. Appendages.

1. Swimmerets.
   6 Pair.
2. Legs.
   4 Pair.
3. Forceps.
   1 Pair.
4. Maxillipedes.
   3 Pair.
5. Maxillæ.
   2 Pair.
6. Mandibles.
   1 Pair.
7. Antennæ.
   1 Pair.
8. Antennules.
   1 Pair.
9. Eye-stalks.
   1 Pair. Total, 20 pair.

V. Gills.

Second pair Maxillipedes.
2 Pair.

Third pair Maxillipedes.
3 Pair.

Forceps.
3 Pair.

Chelate limbs.
6 Pair.

Legs (1st).
3 Pair.

Legs (2d).
1 Pair. Total, 18 pair.

DIRECTIONS.

Boil the cray-fish, and have each pupil dissect and mount one on cardboard.

Keep a few specimens alive to develop by experiment facts on locomotion, respiration, digestion, circulation, molting, reproduction.

Have on the teacher's desk "The Cray-fish", by T. H. Huxley.

EXPERIMENTS.

1. Cause the cray-fish to walk and swim backwards and forwards. Explain these movements.

2. Half cover a live cray-fish with water.

Drop ink by the side of abdomen. Watch for it to issue in front.

3. Keep the animal until hungry. Feed it a bit of meat. Watch the process.

4. Boil the specimen. Explain change of color.

5. Place carapace in vinegar. Explain bubbles.

FROGS AND TOADS

Point out distinctions. Observe in each.

1. Head.
2. Tongue.
3. Teeth.
4. Body.
5. Covering.
6. Legs.
7. Color.

Teach what tadpoles will become frogs and what toads—the latter being darker in color.

Show that the eggs of frogs are in glairy masses—toads in strings like beads.

Dissect a frog—following one of the many accessible guides.

EXPERIMENTS ON THE FROG.

1. Put pieces of wet paper over nasal openings of a live frog.
2. Watch the movements in throat and sides.
3. Fasten the mouth open.
4. Hold the tongue outside of the mouth.
5. Wet the back and sides with a few drops of ether.
6. Place the web of hind foot under the microscope.

The frog having no diaphragm, needs to work the mylo-hyoid muscle in order to force air into the lungs, or to expel it from the nasal openings.

The two lobes of the tongue serve as valves to the posterior nasal openings—thus controlling the ingress and egress of air.

EXAMINATION OF PERCH.

STUDY.

1. Shape.
2. Size. How measure?
3. Covering.
4. Divisions.
5. Fins.
6. Movements.
7. Specific gravity.
8. Growth.
9. Habits.

Have all carefully examine operculum, lateral line, muciparous glands, mouth, teeth, tongue, scales, color.

Dissect the Perch. One specimen will serve two pupils.

THE WORK TESTED.

Apply these topics to the Cray-fish and Perch:

1. Covering.
2. Swimming.
3. Location and function of the heart.
4. Direction of the water when passed over the gills
5. Alimentary canal.
6. Reproduction.
7. Development and growth.
8. Habits.

A HEN'S EGG.

1. Boil and examine for *three* membranes, white, yolk, and embryo.

2. In *all* boiled eggs, why is the yolk *always* nearer one side than the other?

3. Shake a fresh egg and make it stand on either end.

4. Why are eggs turned in the nest?

5. Place an egg in vinegar.

6. What is the process of "blowing eggs" for cabinet exhibition?

7. Bore a hole in the small end of an egg, and place the perforated end in a wine glass. Set the glass and egg under the receiver of an air-pump. Exhaust.

EXAMINATON OF PIGEON.

STUDY.

1. Head.
2. Neck.
3. Body.
4. Wings.
5. Tail.
6. Legs.
7. Toes.

Explain and apply the following terms: Bill, apex, culmen, tomia, nostrils, cere, upper mandible, lower mandible, crown, gula, primaries, secondaries, tertiaries, coverts, tail, tarsus, hallux.

Where begin to count toes?

Dissect the pigeon.

WORK ON A FEATHER.

The pupils are to be furnished with like specimens.

1. Point out quill, shaft, after-shaft, vexilla, vane, barb, barbules. The after-shaft is wanting in tail-feathers.

1. Move a feather backward and forward.
2. How are the feathers of a fan set? Reasons in full.
3. Purpose of wing-coverts and tail-coverts.
4. Explain altricial, nidification, monogamous, preening.

DISSECT A CAT.

Place a small, lean cat in a box covered with a pane of glass.

Saturate a small sponge with chloroform and throw in the box.

In three minutes, the cat will be insensible. Five minutes later, commence work.

Follow the directions in Prof. B. G. Wilder's book on the cat.

If this work has been done in the study of physiology, it will have added interest now.

Take some typical vertebrate, and with the aid of a good book have the class state facts pertaining to the following:

1. Notochord.
2. Bilateral symmetry.
3. Dorsal and ventral sides.
4. Head and neck.
5. Relative position of eyes, ears, and nose.
6. Spinal column.
7. Parts of digestive tract.
8. Lungs or gills.
9. Red blood except—
10. Appendages.
11. Covering.
12. Reproduction.

The above guide when put in terse statements, express the "characters" of vertebrates.

A "character" in zoology is a peculiarity in structure, function, or habit, that belongs in common to all animals in that group.

In like manner bring out the characters of the following classes of the branch Vertebrata.

MAMMALIA.

1. Rearing of young.
2. Covering.
3. Lower jaw.
4. Quadrate bone.
5. Teeth.
6. Diaphragm.
7. Blood.
8. Brain and nervous system.
9. Appendages.
10. Lungs.
11. Senses.
12. Reproduction.

AVES.

1. Covering.
2. Wings.
3. Digits.
4. Clavicles.
5. Condyle (occipital).
6. Quadrate bone.
7. Heart.
8. Lungs.
9. Diaphragm.
10. Brain.
11. Senses.
12. Digestive tract.
13. Oology.
14. Nidification.
15. Reproduction.

REPTILIA.

1. Vertebrae.
2. Ribs
3. Sternum.
4. Covering.
5. Heart.
6. Condyle (occipital).
7. Quadrate bone.
8. Limbs.
9. Eyes.
10. Nostrils.
11. Tongue.
12. Lips and salivary glands.

BATRACHIA.

1. Gills at some time.
2. Metamorphosis.
3. No fins.
4. Condyles.
5. Heart.
6. Sternum.
7. Brain.
8. Senses.
9. Covering.
10. Habits.
11. Reproduction.

PISCES.

1. Lower jaw.
2. Fins.
3. Vertebrae.
4. Brain.
5. Gills and air-bladder.
6. Heart.
7. Liver.
8. Sternum.
9. Covering.
10. Growth.
11. Classes.

The chief "characters" of the orders of Mammalia and Aves are presented to help teachers in guiding the observation of children in the study of types.

PRIMATES.

Teeth uneven and interrupted. Never more than four incisors in each jaw.

In higher forms, the pollex, and sometimes the hallux, opposable to the other digits.

Man belongs to the family Hominidae, Genus Homo, Species *Sapiens.* He is distinguished from all other beings by having *flat nails*, *erect posture*, and *unlimited power*.

CHEIROPTERA.

Three kinds of teeth. Fore limbs with four digits united with membrane. Thumb free and furnished with claw—used in sleep.

Eyes small Ears often large. Nocturnal.

INSECTIVORA.

Plantigrade. Three kinds of teeth. Incisors, short, simple. Five toes, furnished with claws. Clavicles.

Limbs short, weak. Brain without convolutions. Mostly nocturnal.

CARNIVORA.

Three kinds of teeth. Claws sharp. Mammae abdominal. Clavicle rudimentary. Stomach simple.

GLIRES.

Each jaw with two long incisors. No canines. Clavicles present. Incisors beveled on inner face. Enamel organ persistent. Upper lip often divided.

PROBOSCIDEA.

Incisors present. First pair deciduous. A proboscis. Mammae pectoral. One molar at a time in each jaw. No clavicles. Stomach large, simple. No gall-bladder. Each foot has five toes. The hand longer than the foot. Femur vertical to the body-axis.

UNGULATA.

Two sets of teeth of highest rank. Clavicles wanting. Digits never exceed four. Hoof or hoofs present. Mammae inguinal. Horns in some families. Stomach not uniform in structure.

Most important to man.

SIRENIA.

Horizontal fin. No external ears. Mammae thoracic. No hind limbs. Six cervical vertebrae in manatee.

CETE.

Body fish-like. Tail horizontal. Covering smooth—without hair. Layer of fat beneath the skin. Appendages without leverage system. Nasal cavities usually at top of head. No sacrum. No clavicles. Teeth uniform, if present.

BRUTA.

Teeth generally wanting. If present, no enamel, no roots.
Tongue long. Insectivorous animals.

ORDERS OF AVES.

The characters of the orders of Aves are here presented with the statement that Grallatores and Natatores are names of older classification, but retained for simplicity.

PASSERES.

Bill various, never arched. No cere. Feet strong, three toes in front, one behind—all on a level—none versatile. Musical apparatus well developed. Sternum of uniform pattern. Highest order of Aves. Respiration and circulation the most rapid of birds.

PICARIAE.

Not strongly marked. Bill various. No cere. Hind toe small; sometimes wanting—occasionally elevated—its claw shorter than that of middle toe.

Legs small, weak. Wings strong.

PSITTACI.

Bill short, stout, arched, hooked at tip—assists in climbing. Cere at base.

Upper mandible a complete hinged joint. Tongue fleshy. Clavicles weak or absent. Outer and inner toes turned backward. Feet used as hands.

RAPTORES.

Bill arched—hooked at tip. Nostrils in cere at base. Legs stout. Inner toe turned back. Claws hooked, sharp, partly retractile.

Owls.—Eyes forward. Outer toe reversible.

Hawks.—Eyes lateral. Head feathered. Claws sharp.

Vultures.—Eyes lateral. Head bare. Claws blunt.

COLUMBAE.

Bill various. Nostrils pierced in membrane. Hind toe on a level with the rest. Claws short—slightly curved. Wings strong. No gall bladder. Arboreal, altricial, monogamous.

GALLINAE.

Bill short—edges of upper mandible overlapping the lower. Nostrils in membranous space. Legs large—feathered to knees, claws stout, hind toe elevated. Body bulky. Wings weak. Polygamous—not altricial.

GRALLATORES.

Bill longer than head. Neck long. Legs long,—naked above the knees,—toes not webbed. Body thin, compressed. Are waders. Many can swim. Polygamous, altricial.

NATATORES.

Bill flat. Legs short—back of center of gravity. Toes webbed. Body heavy—covered with two coats of feathers. Water birds. Polygamous—not altricial.

CLASSIFY THE FOLLOWING:

Crow.
Hawk.
Humming-bird.
Stork.
Plover.
Wren.
Blackbird.
Snipe.
Crane.
King-fisher.
Auk.
Goose.
Parrot.
Loon.
Cormorant.
Owls.
Cuckoo.
Whippoorwill.
Night-hawk.
Reed-bird.
Meadow-lark.
Vulture.
Quail.
Rail.
Duck.
Ostrich.
Pigeon.
Pelican.
Shrike.
Bluejay.

OUTLINE OF ANIMAL KINGDOM.

Branch I.

Vertebrata.

Class I. Mammalia.

a. Monodelphia.
  1. Primates.
  2. Cheiroptera.
  3. Insectivora.
  4. Carnivora.
    1. Felidae.
    2. Canidae.
    3. Mustelidae.
    4. Ursidae.
    5. Procyonidae.
    6. Otariidae.
    7. Phocidae.
  5. Rodentia.
  6. Proboscidea.
  7. Ungulata.
    1. Camelidae.
    2. Giraffidae.
    3. Ovidae.
    4. Bovidae.
    5. Cervidae.
    6. Hippopotamidae.
    7. Suidae.
    8. Equidae.
    9. Rhinocerotidae.
    10. Tapiridae.
  8. Sirenia.
  9. Cete.
  10. Bruta.

b. Didelphia.

c. Ornithodelphia.

OUTLINE OF ANIMAL KINGDOM—Continued.

Class II. Aves.

  Sub-class.

- 1. Carinatae.
    - 1. Passeres.
    - 2. Picariae.
    - 3. Psittaci.
    - 4. Raptores.
    - 5. Columbae.
    - 6. Gallinae.
    - 7. Grallatores.
    - 8. Natatores.
- 2. Ratitae.

Class III.

  Reptilia.

- 1. Crocodilia.
- 2. Chelonia.
- 3. Lacertilia.
- 4. Ophidia.

Class IV.

  Batrachia.

- 1. Anura.
    - 1. Ranidae.
    - 2. Bufonidae.
- 2. Urodela.
- 3. Proteida.
- 4. Trachystomata.

Class V.

  Pisces.

- Sub-class I.
    - Teleostei.
- Sub-class II.
    - Ganoidei.
- Sub-class III.
    - Elasmobranchii.

OUTLINE OF ANIMAL KINGDOM—Continued.

- Class VI.
  - Marsipobranchii.
- Class VII.
  - Leptocardii.

Branch II.
- Arthropoda.
  - Class I.
    - Insecta.
      - Sub-class Hexapoda.
        1. Hymenoptera.
        2. Lepidoptera.
        3. Diptera.
        4. Coleoptera.
        5. Hemiptera.
        6. Orthoptera.
        7. Neuroptera.
        8. Thysanura.
      - Sub-class Arachnida.
        1. Araneina.
        2. Pedipalpi.
        3. Acarina.
      - Sub-class Myriopoda.
  - Class II.
    - Crustacea.
      1. Trilobita.
      2. Decapoda.
      3. Tetradecapoda.

Branch III.
- Mollusca.
  - Class I.
    - Cephalopoda.
  - Class II.
    - Cephalophora.
  - Class III.
    - Lamellibranchiata.

Branch IV.
- Vermes.

Branch V.
- Echinodermata.

OUTLINE OF ANIMAL KINGDOM—Continued.

Branch VI.
    Coelenterata.

Branch VII.
    Porifera.

Branch VIII.
    Protozoa.

The outline as here given is *meager*, but experience will show that one term is a very short time to intelligently study all its parts.

The etymology of all the words should be required, and illustrations given for all the groups.

As most of the words are not found in a dictionary, a hint may be helpful as to pronouncing them.

In the endings *poda* and *idae* the accent falls on the antepenultimate, as in Arthopoda and Felidae.

Classifying animals by learning schemes and memorizing characters with no animals in sight, should be called "cram," not zoology.

CLASSIFY:

Cricket.
Starfish.
Hornet.
Tree frog.
Turtle.
Bat.
Sponge.
Rat.
Leech.
Moth.
Amphioxus.
Sea anemone.
Perch.
Louse.
Potato bug.
Squid.
Lobster.
Mule.
Jelly-fish.
Trichina.
Sturgeon.
Cobra.
Opossum.
Mole.

The teacher must not forget to generalize. The class must be shown by example how to treat topics like these:

1. Prehension in animals.
2. Locomotion.
3. Respiration in Arthopoda and Pisces.
4. Location and function of the heart in cray-fish, perch, and frog.
5. Covering of mammals.
6. Alimentary canal in the different Branches.
7. State the value of any one of the five senses from the lowest animal to the highest.
8. Reproduction in *invertebrata*.

CHEMISTRY.

In starting a class in this study, the teacher must decide two things:

1. The amount of work.
2. The kind of work.

As some elements are more important than others, it may not be best to use the text-book as it reads, but to choose twenty elements from the list and spend the term upon *them.*

These elements may be the following, with their atomic weights:

H = 1
Cl = 35.5
I = 126.5
Na = 23
K = 39
Ag = 108
O = 16
Cu = 63.5
Zn = 65
Fe = 56
Mn = 55
S = 32
Pb = 207
Hg = 200
Ba = 137
Ca = 40
N = 14
P = 31
Au = 196.5
C = 12

On examining the twenty elements chosen, there will be found six univalents, twelve bivalents, three trivalents, and one quadrivalent—all in the order given.

This table of atomic weights should be perfectly memorized, as on this table hinges all the mathematical work of chemistry for the term.

Show, by experiment of placing Na in air, that O combines with it, and that $2\ Na_2 + O_2 = 2\ Na_2O$.

The above experiment is represented by the symbols forming an equation. Hence a chemical equation is the representation of a chemical experiment and its result.

There are theoretical equations, but it is presumed that no equations will be given or required that do not belong to experimental work.

The first member of an equation represents the elements or compounds used. The second member shows what compounds or elements set free.

It is well to start the work in problems early. Every problem helps to fix an experiment. The simplest are those concerning molecular weight.

What is the molecular weight of sodic oxide?

$$\text{Sodic oxide} = Na_2O$$
$$46 + 16$$
$$Na_2O = 62.$$

46, 16, and 62 express the number of microcriths. As a microcrith is represented by a hydrogen atom, all these numbers could be marked H.

What part of hydric oxide is O?

$$2 + 16$$
$$H_2O = 18$$
$$O \text{ is } \tfrac{16}{18} \text{ or } \tfrac{8}{9} \text{ of } H_2O.$$

Pupils are interested at once in representing, in a short way, the common objects about them, as salt, lime, chalk, ammonia, hydrochloric acid.

What part of each is the metal?

The following principles may be helpful at this stage of the work:

SIX PRINCIPLES.

I.—The Balance.

All processes in chemistry are determined ultimately by the balance.

II.—Symbols.

All symbols of elements represent them in vapor state.

III.—Chemical Affinity.

Chemical affinity exists between atoms only, and is most intense when the atoms are most unlike.

IV.—Atoms.

Atoms are of two kinds—like and unlike. Like atoms form elements; unlike atoms form compounds.

V.—COMPOUNDS.

In representing compounds, place the symbol which stands for the metal first. In reading compounds, make an adjective of the first word of the full name.

VI.—PROOFS OF CHEMICAL ACTION.

Heat, light, and electricity usually attend chemical action.

Parallel with this work comes experimentation.
Physical changes are presented first.

EXPLAIN:

1. Writing with chalk, pencil, ink.
2. Pop corn, making bread, vinegar.
3. Making butter, baking potatoes.
4. The wetting of plaster of Paris, the burning of a lamp.
5. Formation of gum, the drying of paint.

Make sharp distinctions between the physical and chemical changes in many of the topics named.

The experiments best understood and longest remembered are those performed by the pupils.

The writer has found that it is a good plan to place in the hands of the pupils some dangerous substance, as sodium or phosphorus, at the beginning of their work. There are two reasons for this:

1. Pupils learn what cautions mean.
2. Ever after they are ready to heed them.

Sodium is an excellent element with which to begin the study of chemistry. The outline of work with this element may be taken as a type of several other elements treated *only* in outline.

Na.
- I. Definition.
- II. Describe.
- III. Preparation.
- IV. Cautions.
  1. Keep under naphtha.
  2. Handle with dry fingers.

OUTLINE OF SODIUM—Continued.

V. Properties.
  1. Physical.
    1. Hardness.
    2. Color.
    3. Melts.
    4. Specific gravity.
  2. Chemical.
    1. Affinity for O.
    2. Reducing agent.

VI. Abundance.

VII. Salts.
  Na_2O
  $NaCl$
  Na_2SO_4
  Na_2CO_3
  $NaHCO_3$
  $NaHO$
  $NaNO_2$
  $NaNO_3$

VIII. Test.
  Color of flame.

EXPERIMENTS:

1. Cut and handle.

2. Place a small piece in air.

3. Throw a small piece on water. (Observe and explain).
    1. It melts.
    2. Shape.
    3. Two motions.
    4. Becomes smaller.
    5. Onward motion increases.
    6. Leaves a track. (Test with red litmus paper.)
    7. Test the water with fingers.
    8. Catch escaping H.
    9. Explosion at the last.

CHEMISTRY OF THE EXPERIMENTS:

I.

$$Na_2 + H_2O = Na_2O + H_2$$
$$Na_2O + H_2$$

II.

$$Na_2O + H_2O = 2\,NaHO$$
$$Na_2\ H_2\ O_2$$

Breathe on a few drops of $NaHO$.

$$\text{Hence, } 2NaHO + CO_2 = Na_2CO_3 + H_2O$$
$$Na_2CO_3 + H_2O$$

PROBLEM:

How many grains of Na acting on H_2O will liberate one gallon H?

First give the equation.

$$\overset{46}{Na_2} + H_2O = Na_2O + \overset{2}{H_2}$$
$$Na_2O + H_2$$

Hence, 46 parts Na acting on H_2O liberates 2 parts H; and 46 grains Na acting on H_2O liberates 2 grains H; and 23 grains Na acting on H_2O liberates 1 grain H.

100 cubic inches air weighs 31 grains.

231 cubic inches air weighs 71.61 grains.

H is about $\frac{1}{14}$ the weight of air.

Hence, 1 gallon H weighs 5.114 grains.

Since 23 grains Na acting on H_2O liberates 1 grain H, to liberate 5.114 grains H 5.114×23 grains Na will be required on 117.622 grains.

It has been observed that no directions for manipulation or descriptions of experiments have been given.

Consult any good text-book for cautions and methods.

The study of potassium may be much simplified by using sodium for experiments, on account of its cheapness, and limit the use of potassium to handling and cutting. The properties and behavior of both elements are much the same.

POTASSIC SALTS:

KCl
K_2O
K_2SO_4
K_2CO_3
KHO
$KHCO_3$
KNO_2
KNO_3

What part of each is K?

Have the pupils see and handle as many of these salts as possible.

As hydrogen is the standard for several things, pupils should study this element early in the course.

OUTLINE FOR HYDROGEN.

H.

I. Definition.

II. Standard for
  1. Atomic weight.
  2. Volume.
  3. Quantivalence.
  4. Equivalence.

III. Properties.
  1. Physical.
     1. Levity.
     2. Inodorous.
     3. Invisible.
     4. Tasteless.
  2. Chemical.
     1. Strong affinity for O.
     2. Narrow range of affinity for metals.
     3. Essential to acids and alkalies.
     4. Inflammable.

IV. Cautions.
  1. Never use till tested.
  2. Use soon after liberation.

V. Tests.
  1. Burn at mouth of test-tube.
  2. Hold cold plate over philosopher's lamp.

LIBERATION.

Place Zn in *five* parts H_2O and *one* part H_2SO_4 by volume.

REACTION.

$$\begin{array}{l} 130. \qquad\qquad\qquad 2\,(65 + 32 + 64) = 322 \\ Zn_2 + 2\,H_2SO_4 = 2\,Zn\,SO_4 + 2\,H_2 \\ 2\,Zn\,SO_4 + 2\,H_2 \end{array}$$

PROBLEM:

How much $Zn\,SO_4$ will be formed by the action of one pound of Zn on H_2SO_4?

From the above equation it appears that: 130 parts Zn acting on H_2SO_4 form 322 parts $Zn\,SO_4$.

Hence, 130 grains Zn acting on H_2SO_4 form 322 grains $Zn\,SO_4$

1 grain Zn acting on H_2SO_4 form $\frac{161}{65}$ grains $Zn\,SO_4$

7000 grains Zn acting on H_2SO_4 form $7000 \times \frac{161}{65}$ grains, or 17338.4 grains.

EXPERIMENTS:

1. Collect by displacement.
2. Show lightness.
3. Soap bubbles. (Explode.)
4. Diffusion.
    1. By test-tubes.
    2. Porous cup.
5. Balloon.
6. Weigh.
7. Bell experiment.
8. Dip.
9. Pour.
10. Hydrogen fountain.
11. Philosopher's lamp.
12. Musical flame.
13. Hydrogen gun.
14. Sensitive flame.

OXYGEN.

Oxygen, the most important of the elements, is one-tenth heavier than air, and is an odorless, tasteless, colorless gas.

It is a supporter of combustion, unites with all elements but one, and combines at all temperatures.

It acts as a bivalent under all conditions.

LIBERATION.

Estimate the number of gallons wanted. Take one-half as many ounces of $KClO_3$ as gallons of O required. Mix the $KClO_3$ with one-fourth its weight of MnO_2. Place the mixture in an iron or copper retort having a tube of, *at least*, one-half inch bore.

CAUTIONS.

1. Be sure there is no C in the MnO_2. This is known by heating the MnO_2 red hot, when the C will scintillate and unite with the O in the air and form CO_2.
2. Incline the retort.
3. Heat the upper part of the retort first.
4. Regulate the heat to suit the liberation of the O.
5. Use a wash-bottle.
6. Disconnect the apparatus before removing the heat.

EQUATION.

$$2\,KClO_3 + MnO_2 + \text{Heat} = 2\,KCl + MnO_2 + 3O_2$$
$$2KCl + MnO_2 + 3O_2$$

In the equation it appears that the heat is used up in overcoming the chemical affinity between the KCl and the O.

The MnO acts by catalysis as it remains in the retort unchanged. It is probable that MnO_2 serves two purposes:

1. To draw off some of the heat, thus rendering the evolution of the O more even.
2. It is believed that under the influence of heat, MnO_2 undergoes higher oxidation and then parts with the O. Sand and pounded glass will not do as well, though such a statement is sometimes made.

PROBLEMS:

1. One pound of $KClO_3$ will liberate how much O?

2. To liberate 25 gallons O, how much $KClO_3$ is required?

3. If one pound of H_2O is decomposed by electricity, how many gallons of O and H set free?

CALCIUM.

It may be well to work on some of the common salts of this element, such as lime, marble, gypsum.

The book will guide in the study of these compounds, and will also show that they are written CaO, $CaCO_3$, $CaSO_4 . 2 H_2O$.

What part of each is O?

The period in the last expression shows that a molecule of calcic sulphate is in chemical union with two molecules of water.

When heat is applied (248° F.), the water of composition is driven off and plaster of Paris remains. Thus:

$$CaSO_4 . 2 H_2O + \text{Heat} = CaSO_4 + 2 H_2O.$$
$$CaSO_4 + 2 H_2O.$$

PREPARING A CRAYON.

Direct the pupils to thoroughly pulverize and mix one tablespoonful of plaster of Paris and two of whiting. Before wetting the mixture, each should prepare a mold, made by rolling a card to the proper size and shape and tying it with a thread.

Make the mixture plastic with water, and with the fingers force it in the mold.

Lay the crayon by the stove or on the table in a warm room. As soon as dry remove the card and test it.

The first member of the equation would stand thus:

$CaCO_3 + CaSO_4 + 2 H_2O =$? Write the second member.

Fully explain this work. What changes are physical? What are chemical?

PROBLEMS:

1. How many grains of H_2O required to change a pound of plaster of Paris to gypsum?

2. What would be the weight of the plaster of Paris formed from five pounds of gypsum?

LIME.

In order to understand the use and action of lime, it is necessary that pupils *work* with it.

Lime is prepared by heating, in a reservoir, limestone, or calcic carbonate. Thus:

$$CaCO_3 + \text{Heat} = CaO + CO_2$$
$$CaO + CO_2$$

Lime, or CaO, has great affinity for two things —H_2O and CO_2.

CaO, exposed to the air, takes from it H_2O and CO_2, and becomes air-slacked lime.

In a jar of H_2O place a lump of fresh CaO. The water soon becomes milky. The experiment is two-fold. Some of the H_2O is in chemical union with the CaO, and the excess of the latter goes to the bottom.

EQUATION.

$$CaO + H_2O = Ca\ (HO)_2$$
$$CaH_2O_2$$

Let the jar of limewater stand until clear, then filter into a clean bottle.

This CaH_2O_2, or calcic hydrate, is a valuable test for CO_2, and should be carefully stoppered with cork, not glass. Why?

The fluid that has passed the filter is called the *filtrate*, and that which remains *on* the filter the *precipitate*.

Pour a little of the filtered CaH_2O_2 in a test-tube and breathe in the tube. Close the tube and shake.

Observe the changing color. Repeat the experiment until the fluid looks milky.

The precipitate formed is chalk.

EQUATION.

$$CaH_2O_2 + CO_2 = CaCO_3 + H_2O.$$
$$CaCO_3 + H_2.$$

Breathe in a pint jar after pouring into it a tablespoonful of CaH_2O_2. Close the jar and shake.

Hold an inverted pint jar over the flame of a lamp or candle for a few seconds.

Test for CO_2 with Ca_2H_2O.

Take sand (SiO) and CaO in proper proportions, mix and wet with H_2O.

What are "proper proportions?"

On wetting the lime, CaH_2O_2 is formed, which covers the particles of sand on all sides.

CaH_2O_2 has great affinity for CO_2 in the air.

When the mortar is dry and hard, the sand is held in by the new-formed calcic carbonate.

EQUATION.

$$SiO + CaO + H_2O = SiO + CaH_2O_2.$$
$$SiO + CaH_2O_2.$$

Why is hair mixed with the mortar?

When the mortar is spread it is called plaster.

It now undergoes one physical and one chemical change:

1. The water (not of composition) evaporates.
2. CO_2 in the air combines with it.

EQUATION.

$$SiO + CaH_2O_2 + CO_2 = SiO + CaCO_3 + H_2O.$$
$$SiO + CaCO_3 + H_2O$$

MERCURY.

Hg is called one of the *noble* metals. Why?

It melts at 39° F. Explain.

Read about its physical and chemical properties.

Furnish all pupils with Hg in a cup or saucer.

Remove all rings and other articles of gold from its presence. Why?

1. Pour some Hg in H_2O.
2. How remove the H_2O? Use blotting-paper.
3. How clean Hg?
    1. Pour through a funnel of writing-paper.
    2. Stir in granulated sugar and pour Hg off.
    3. Choose two clean dishes. Pour from one to the other. Continue this, cleaning the dish each time.

4. Pour a little Hg on the table. How get it into the dish? Use two cards, one to take it and one to drive it.

All this is play for pupils, young or old. It prepares the way for the following

CHEMICAL EXPERIMENTS:

1. In a mortar place a piece of Na about the size of a pea, and a globule of Hg one-half as large. If the Na does not take fire at once, press the elements with the pestle, the hand being protected.

EQUATION.

$$2\ Na_2 + Hg_2 = 2\ Na_2Hg$$
$$2\ Na_2Hg$$

The compound formed is called sodic amalgam.

An amalgam is the compound formed by the union of mercury with any metal.

There is but one metal that can be used for vessels to hold Hg. What is it?

Handle the Na_2Hg with dry fingers. Examine its properties.

Throw the Na_2Hg into a test-tube half filled with H_2O. Watch the bubbles. Apply a lighted match.

See the Hg in the bottom of the tube.

EQUATION.

$$2\ Na_2Hg + 2\ H_2O = 2\ Na_2O + Hg_2 + 2\ H_2$$
$$2\ Na_2O + Hg_2 + 2\ H_2$$

Test the water with thumb and finger. Dip into it red litmus paper.

Another experiment has been going on unobserved: The sodic oxide, when formed, united at once with the water, and formed sodic hydrate.

EQUATION.

$$Na_2O + H_2O = 2\ NaHO$$
$$Na_2H_2O_2$$

From the above equations it appears that the smallest quantity of a substance is always taken that will satisfy the quantivalence of the elements, and at the same time guard against representing an atom alone in any reaction.

In the equation next to the last, the mercury set free might be represented by Hg, but the smallest quantity of a substance that can be shown in an equation is a molecule. Hence, Hg_2 in the result, requires that the first member be multiplied by two.

Again, the last equation shows that a figure at the left of symbols multiplies molecules. If placed below and at the right of a symbol, it multiplies atoms.

Illustration: $3 H_2 S O_4$ represents three molecules of sulphuric acid. 2 and 4 show the number of atoms of H and O in the compound.

In finding the molecular weight of compounds, this principle must be fully understood.

EXAMPLE:

What part of cupric nitrate is N?

$Cu (NO_3)_2$ = cupric nitrate.

$63 + (14 + 48)_2$

$Cu (NO_3)_2 = 187$

N is $\frac{28}{187}$ of $Cu (NO_3)_2$

The 2 at the right of the parenthesis becomes a factor of all that is enclosed.

Dip a pin in H_2O, then in Hg. It looks like a silver pin.

Wetting the pin favored the action of the metal on the acid. The last act brought about amalgamation.

It is in this way we have "fire gilt" articles. Au is dissolved in Hg—forming gold amalgam.

The articles are dipped in acid, and gold amalgam is then spread over them. The Hg is driven off by heat, and the gold remains.

The preparation of mirrors involves the principles above stated.

SILVER.

Ag is another noble metal. Its source and properties are easily known by reading. But *we* must *work* with it.

EXPERIMENTS:

1. Stir the contents of a boiled egg with a silver spoon. Examine the spoon an hour after. It appears covered with a dark colored film, almost black, not easily removed.

The hydric sulphide (H_2S) in the egg has combined with the Ag, forming argentic sulphide (Ag_2S).

EQUATION.

$$2\ Ag_2 + 2\ H_2S = 2\ Ag_2S + 2\ H_2$$
$$2\ Ag_2S + 2\ H_2$$

This silver tarnish formed in this way, or from the escaping gas from the stove or gas-jet, is quickly removed with ammonia and common soap.

2. Furnish each pupil with a little dilute HNO_3. (Dilute acid means 3 parts H_2O and 1 part acid by volume.)

Hold a silver coin in the acid long enough to see evidences of chemcal action.

The silver "has acted on the acid," forming $Ag\ NO_3$. What is the meaning of the quotation?

In electricity, the positive pole draws to it negative elements.

Since the metals are positive when compared with non-metals, they are supposed to begin chemical action. It may be proper to add that this fact explains why the symbol for the metal takes precedence in the expression of a compound.

To a portion of the dissolved Ag, seemingly none, add a drop of HCl. Notice the white precipitate.

EQUATION

$$Ag\ NO_3 + HCl = AgCl + HNO_3$$
$$Ag\ Cl + HNO_3$$

The limits of this pamphlet forbid treating each of the twenty elements chosen, as shown with Na, H, O, Ca, Hg, Ag.

The ingenious teacher will devise experiments of his own, and he alone can know what and how many problems to give.

From the little work done, it is easy to see that there need be no *theoretical* equations in elementary chemistry.

A few outlines are shown, without comment.

N.

I. Definition.

II. Describe.

III. Sources.

- 1. Saltpeter.
  - 1. Indian, KNO_3.
  - 2. Chilian, $NaNO_3$.
- 2. Animal tissues.
- 3. Plants.

IV. Preparation.

4 oz. $KNO_3 + 2\frac{1}{2}$ oz. H_2SO_4 + gentle heat.

V. Properties.

- 1. Physical.
  - 1. Non-supporter of combustion.
  - 2. Colorless.
  - 3. Tasteless.
  - 4. Odorless.
  - 5. Coercible.
- 2. Chemical.
  - 1. Forms unstable compounds.
  - 2. Forms acids with O.
  - 3. Forms bases with H.

VI. Compounds.

N_2O
$N_2 O_2$
NO_2
$N_2 O_3$
$N_2 O_4$
$N_2 O_5$
NI_3
H_4N
H_3N
$H NO_3$

EXPERIMENTS:

1. Burn the O in a jar of air with P on a cork over H_2O. N remains. Test with flame.

2. Rub a warm knife blade over wax or paraffine. Write a name with a pin through the wax to the steel. Pour on dilute $H NO_3$. The name is etched on the blade.

3. Gently heat 1 oz. $H_4N . NO_3$ and collect the N_2O over H_2O. Experiment with the gas as with O.

C.

I. Definition.

II. Describe.

III. Source—Living objects.

IV. Forms.

1. Crystalline.
   1. Diamond.
   2. Graphite.
2. Amorphous.
   1. Coal.
      1. Anthracite.
      2. Bituminous.
      3. Charcoal.
      4. Cannel.
   2. Soot.
   3. Lampblack.
   4. Boneblack.

V. Properties.

1. Physical.
   1. Solid.
   2. Unchangeable.
   3. Insoluble.
   4. Absorbent.
2. Chemical.
   1. Feeble affinity except at high heat.
   2. Wide range of combination.
   3. Feeds all vegetable life in the form of CO_2.

VI. Uses.

1. Fuel.
2. Light.
3. Polish.
4. Printing.
5. Conductors.
6. Insulators.
7. Ornament.

VII. Compounds.

1. CO
2. CO_2
3. $CH\ Cl_3$ Chloroform.
4. $C_2\ H_6O$ Alchhol.
5. $(C_2\ H_5)_2O$ Ether.
6. $C_6\ H_{10}\ O_5$ Starch.
7. $C_{12}\ H_{22}\ O_{11}$ Sugar.

ONE LAW OF CARBON.

Burn carbon slowly for light and quickly for heat.

EXPERIMENTS:

1. Pour HCl on boneblack, and stir with glass rod. Add H_2O and wash until the acid is removed. Dry and use as a filter.

2. Filter tea, ink, coffee, and indigo. If all these are not colorless the first time, repeat. Each will lose its odor.

CO_2.

I. Definition.

II. Describe.

III. Sources.

- 1. Free in nature.
  - 1. Respiration.
  - 2. Combustion.
  - 3. Fermentation.
  - 4. Decomposition.
- 2. Found in all carbonates.

IV. Properties.

- 1. Physical.
  - 1. Specific gravity.
  - 2. Colorless.
  - 3. Coercible.
  - 4. May be solidified.
- 2. Unites readily with most bases.

V. Preparation.

Treat chalk or marble with HCl or H_2 SO

VI. Collect by displacement.

Since there is no gas of the same weight as air, all gases may be collected by displacement of air, providing such gas does not combine with the free O as in case of NO.

EXPERIMENTS:

I. Test its presence.
  - 1. With lighted taper.
  - 2. Litmus paper.
  - 3. $Ca\ H_2\ O_2$.

2. Pour.
3. Dip.
4. Weigh.
5. Chemical vacuum.

Cover the bottom of the jar with Na HO. Fill the jar with CO_2. Cover with bandage rubber and tie down. Shake the jar.

P.

I. Definition.

II. Describe.

III. Sources.

The three kingdoms of nature.

IV. Preparation.

1. (a) Bones heated by steam.
   (b) Mineral matter treated with $H_2 SO_4$.
   (c) Products, $Ca SO_4$, $CaO . P_2 O_5$.
2. (a) $Ca SO_4$ filtered away.
   (b) Charcoal added to super-phosphate of lime.
   (c) Apply heat.
3. P distills over and condenses.
4. P is purified under chromic acid—$H_2 CrO_4$.

V. Properties.

1. Physical.
   1. Solid.
   2. Tasteless.
   3. Odor (Garlic).
   4. Specific gravity.
   5. Soluble in CS_2 and $(C_2 H_5)_2O$.
2. Chemical.
   1. Inflammable.
   2. Reducing agent.
   3. Luminous.

VI. Cautions.

1. Keep under H_2O.
2. Handle with wet fingers.

VII. Uses.

1. Matches.
2. Medicine.

VIII. Tests.

1. Luminosity.
2. Sodium.

EXPERIMENTS:

1. Analysis of air. (See experiment 1 under N.)
2. Cut and handle.
3. Write on paper.
4. Form $P_2 O_3$ and $P_2 O_5$. Place a small piece of P in a hydrogen-tone-tube. Warm tube at the center, holding it horizontally. When P burns, incline the tube and watch.
5. Place several small pieces of P in hot water (180° F.) and force O, through a glass tube, down upon them. Use a graduate for H_2O.
6. Dissolve P in CS_2. Put one drop of solution on blotting-paper and watch.
7. Cover a small piece of P with lampblack.

S.

- I. Definition.
- II. Describe.
- III. Sources.
  - 1. Lava (Sicily.)
  - 2. Sulphides of metals.
- IV. Preparation.
  - 1. Burning.
  - 2. Sublimation.
- V. Appearance.
  - 1. 250° F., pale yellow.
  - 2. 350° F., black and viscid.
  - 3. 500° F., again liquid.
  - 4. 836° F., boils.
- VI. Allotropic states.
  - 1. Dimorphous.
  - 2. Amorphous.
  - 3. Viscid.
- VII. Solvents.
  - 1. CS_2.
  - 2. $C_{10} H_{16}$.
- VIII. Compounds.
  - 1. SO_2.
  - 2. SO_3.
  - 3. $H_2 SO_4$.
  - 4. Fe S.
  - 5. Zn S.
  - 6. Cu S.
  - 7. $Na_2 S$.
  - 8. $H_2 S$.
- IX. Uses.
  - 1. Gunpowder.
  - 2. Bleaching.
  - 3. Matches.
- X.
  - 1. Color.
  - 2. Odor.
  - 3. $BaCl_2$.

CAUTIONS:

1. Handle with care.
2. If spilled, saturate the object with H_2O and add $H_3 N$.
3. Never pour H_2O into it. Pour the H_2SO_4 into H_2O.

EXPERIMENTS:

1. Insert stick, straw, or cloth in the acid.
2. Write on paper with stick dipped into it.
3. Pour the acid on a lump of sugar.
4. Pour the acid on molasses.
5. Put a drop of $H_2 SO_4$ in a test-tube of H_2O. Add one drop BaCl.
6. Dissolve a piece of shoe-blacking, about the size of a grain of wheat. Add $BaCl_2$ as before.
7. Use for desiccation.
8. Prepare parchment paper.

An outline for work in galvanic electricity is submitted in place of the remaining elements not noticed in the list:

ELECTRICITY.

- I. Definition.
- II. Sources.
  1. Friction.
  2. Chemical action.
  3. The earth.
- III. Kinds.
  1. Static.
  2. Dynamic.
- IV. Transmission.
  1. Conduction.
  2. Convection.
  3. Discharge.
- V. Battery.
  1. Definition.
  2. Principles.
     1. There must be two solids and one liquid.
     2. One solid must act on the liquid more than the other.
     3. The greater the difference of chemical action the stronger the battery.
  4. Construction.
     1. Choice of liquid.
     2. Choice of solid.
     3. Amalgamate Zn.
     4. Preparation of liquid.
  5. Care
     1. Keep Zn amalgamated.
     2. Keep solids clean and dry.
     3. Remove plates from liquid when not in use.
  6. Terms.
     1. Poles.
     2. Conductors.
     3. Non-conductors.
     4. Insulators.
     5. Electro-motive force.
     6. Resistance.
     7. Ohm.
     8. Volt.
  7. Effects.
     1. Magnetism.
     2. Chemical action.
     3. Heating.

The bichromate of potash battery is the one here meant.

The solution is prepared by dissolving four ounces bichromate of potash in a gallon of hot water, and when cool adding one and one-half pints of H_2SO_4.

A KEY FOR EXPRESSING COMPOUNDS.

UNIVALENT ACID RADICALS.

NO_2 — forms nitrites. NO_3 — forms nitrates.
ClO_3 — forms Chlorates.

BIVALENT ACID RADICALS.

$CO_3 =$ forms carbonates. $SO_3 =$ forms sulphites.
$SO_4 =$ forms sulphates.

TRIVALENT ACID RADICALS.

$BO_3 \equiv$ forms borates. $PO_4 \equiv$ forms phosphates.

The short lines after the expression of the radical show the amount of affinity it has compared with H.

Thus Na is a univalent. $PO_4 \equiv$ is a trivalent acid radical forming phosphates. Hence, sodic phosphate should be written $Na_3 PO_4$.

WATER-TYPE.

$H - O - H.$

TYPE FOR BASES.

$\overline{R} - O - H.$
$H - O - \overline{R}.$

A metal + $OH =$ a base.
A metalloid + $OH =$ an acid.
Two kinds of bases: Basic anhydrides. Basic hydrates.
Two kinds of acids: Acid anhydrides. Acid hydrates.
A base + an acid = a salt.
Three kinds of salts: Basic, neutral, and acid.
Sixty-eight elements in nature.

All the outlines and suggestions given above are based on the belief that the abiding impressions are to come from the pupils' own work, the teacher being a guide and the text-book an aid. The theory of chemistry should be taught in connection with the laboratory work, instead of before it or after it.

The better plan would seem to be the following:

1. Excite curiosity.
2. Pupils all work.
3. Stimulate inquiry.
4. Cultivate observation.
5. Exercise judgment.

Lastly, when the mind is eager to know, add *the theory* belonging to the *work in hand.*

STAINS.

A stain is an injury to the appearance or texture of a tissue, animal or vegetable.

No allusion is here made to staining or stains for purposes of ornamentation.

All stains are either physical or chemical.

PHYSICAL STAINS.

Stains of a physical character are such as can be removed by physical means—friction, heat, or solvents. Most common among stains are such as come from grease, ink, and the juices of fruits and plants.

Grease is everywhere. We are not to believe that grease is absent because the eye fails to detect its presence. The most cleanly products of the human hand may be made to reveal the presence of its oily touch.

The kerosene in our unlighted lamps is constantly passing off into the air as vapor, and settling upon all objects in the room.

What are some of the facts about greasy substances?

Greasy substances are fats and oils. Fats are solid, and oils are liquid, at ordinary temperatures.

Oils are of two classes—fixed and volatile. Fixed oils decompose at or above 500° Fahrenheit. Volatile oils may be vaporized without decomposition under 500° of heat. Many of these oils evaporate rapidly in the open air.

Fats are dissolved by the fixed oils. Butter, lard, and tallow may be dissolved by linseed, castor, and olive oils.

Fixed oils are dissolved by the volatile oils, as the oils named are dissolved by kerosene, turpentine, and gasoline.

The volatile oils are dissolved by alcohol, *ether*, *and chloroform.*

The application of the above is this: All forms of grease and paints on cotton or woolen fabrics may be dissolved by washing in gasoline. Fresh quantities of the fluid should be used when much grease is to be removed.

Grease and tar on silks and satins should be removed by ether, their most perfect solvent. In the course of many experiments with ether upon various colored silks, it has always proved harmless to the color.

It is not enough to have a ready solvent in order to successfully remove grease, as the following statements will show:

A man discovers a spot of grease on the knee of his pantaloons. Soap and water are applied, and a sponge is vigorously used. The result is a halo of grease around the cleanest spot in the garment. The philosophy is plain. Some of the soap was decomposed by the hot water, and the sodic hydrate has united with the grease of the cloth, and new soap formed. The dry fibers of the cloth have drawn, by capillary attraction, the dissolved grease back from the center of the stain, to the disappointment and chagrin of the manipulator.

The better way is to use the best solvent that is harmless to the cloth. Use as little friction as possible, and be sure that a good absorbent, flannel or blotting paper, is beneath the stain.

Lastly, always apply the solvent on the side opposite the stain. If this is not done, the grease is worked through the fabric, when, in fact, it should be dissolved and fall out.

The truth of this is more apparent in removing paint from silk. The ether is poured upon the side opposite the paint, the oil is dissolved and taken up by an absorbent, and the pigment in the paint stands out loosely on the fibres of the silk, and a simple movement of the finger nail removes it. In this case no friction has been applied to the face side of the silk.

Observe the same directions for removing tar, wheel grease, cream, fats and oils of whatever kind.

Kerosene on books, paper, and thin cloth may be removed without the use of a solvent. Place the paper between blotting-paper, several pieces on each side, and rub either surface with a hot flat-iron. Blotting-paper has stronger attraction for kerosene than sized paper or cloth. The oil not absorbed is vaporized by the heat of the iron. Kerosene on carpets may be removed in this way, but if the spot is large it is better to place the carpet in the sunlight. In the after use of the carpet the woof is likely to draw the oil from the warp and again injure the color. The safest and surest way is to place the carpet in the sunlight, and pour upon the spot a liberal amount of gasoline, and leave it to dissolve the oil and evaporate.

From what has been said, it appears that grease spots *can be removed.* And so they can. Usually, however, only a small portion of grease is removed from the fabric. It is only diffused through the cloth and "lost to view."

CHEMICAL STAINS.

Chemical stains cannot be removed by physical means. Their removal depends upon reagents that will form soluble compounds, hence wash away leaving the fabric clean.

Common among these stains are iron rust, acids, alkalies, iodine, analine, red and black inks, tobacco, nitrate of silver, and grass stains.

Iron rust: The housewife puts lemon juice and salt on the stain, and places the fabric in the sun. Repeated applications of hot HCl quickly removes the stain. The soluble chloride of iron must be washed away with hot water.

Acids: Neutralize all acids with some alkali. If none is at hand, use water to weaken the action of the acid. Cooking soda or saleratus is often better than ammonia in restoring the lost color. Nitric acid stains *stand.*

Alkalies: Alkaline stains are treated with vinegar, or dilute HCl. Whitewash is a common stain on wood and clothing. Its prompt removal with H_2O saves temper and trouble.

Iodine: Iodine stains are common on the skin. Use a solution of potassic iodide (KI).

Analine: All ordinary reagents wholly fail to remove these stains from the skin or from fabrics. Apply HCl (strong) and they instantly disappear. Soluble hydrochlorate of aniline is formed. Thoroughly wash.

Inks: Stains from red ink are simply carmine stains. Ammonia is a ready solvent, but on account of other substances in the ink, alcohol is often better.

Black ink is often very troublesome to remove. A solution of oxalic acid is an excellent agent. If iron is in the ink this application forms oxalate of iron and tannic acid, both soluble. Rinse in dilute ammonia, to avoid a yellow tannic acid stain. For the ready removal of any black ink on white fabrics, use chlorine.

Tobacco: Wash in dilute ammonia.

Nitrate of Silver: Use chlorine, or wash in HCl, and rinse in ammonia.

Grass stains: These stains are obstinate, owing to the adhesion of the chlorophyll to the fabric. Absolute alcohol is an expensive but efficient agent in removing them.

On all ordinary cotton and woolen goods the reagents named are harmless if the fabrics are promptly and thoroughly washed.

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